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Stand Density and Mountain Pine Beetle-caused Tree Mortality in Ponderosa Pine Stands

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Mountain pine beetle-caused tree mortality was monitored in three ponderosa pine plots partially cut to growing stock levels of 60, 80, and 100 and an uncut control. Tree mortality occurred in all plots prior to the partial cutting. No mountain pine beetle-caused mortality has occurred in the partially cut plots since cutting, but tree mortality has continued in the uncut stand. Stands cut to GSL ≤100 appear less susceptible to MPB attack. The critical threshold for MPB infestation may be GSL 120.

Keywords: Mountain pine beetle, ponderosa pine, mortality

Silvicultural treatment of pine stands in the Rocky Mountains shows promise in reducing tree mortality caused by the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins). The first treatments in lodgepole pine (*Pinus contorta* Doug. ex. Loud.) stands removed the most susceptible trees—either by clearcutting or by diameter-limit cutting of the larger diameter trees (i.e., ≥ 12 inches d.b.h.) (Cahill 1978). These treatments greatly reduced tree mortality because they removed the most suitable host material. However, these treatments were not always satisfactory from a timber production standpoint because they left an understocked and uneven-spaced stand of poorer quality, while removing the dominant, more rapidly growing trees.

More recent silvicultural treatments have emphasized partial cutting of susceptible stands to reduce MPB-caused tree mortality. While some of the treatments continue generally to emphasize removing the larger diameter trees through diameter-limit cuts, treatments leaving the best trees with more or less even spacing are equally effective (Amman et al. 1988a, 1988b; Cole et al. 1983; McGregor et al. 1987).

In ponderosa pine (*P. ponderosa* Lawson), silvicultural treatments reduced tree mortality caused by *D. brevicomis* Leconte and *D. jeffreyi* Hopkins in California (Eaton 1959). The treatments were essentially the same type of treatment as those tried later against the MPB in lodgepole pine, i.e., cutting of the larger diameter and "high-risk" trees.

In 1984, partial cutting studies were begun in high-density, susceptible stands of lodgepole and ponderosa pine in the central Rockies. The main objective in both studies was to determine the relationship between stand density and MPB-caused tree mortality after partial cutting removed the smaller diameter, poorly formed, or unhealthy trees and left the larger diameter, healthy trees on more or less even spacing (Schmid 1987). This note reports on the MPB-caused tree mortality at one of the study areas.

Methods

To determine the relationship between stand density and MPB-caused tree mortality, sets of growing stock level (GSL) plots have been installed in susceptible ponderosa pine stands at various locations on the Black Hills National Forest during the past six years. We originally sought stands with basal areas[2] at or exceeding 150 ft^2 per acre and average diameters ≥8 inches d.b.h. because

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[2]*Growing stock level and basal area are equal when the average diameter is ≥10 inches. When the average diameter is <10 inches, basal area is less than GSL. In most of our sets of plots, however, the basal area is ≤5 ft^2 less than GSL when the average diameter is between 8 and 10 inches. Thus, for most cases, basal area and GSL are equal.*

Sartwell and Stevens (1975) identified such stands as conducive for MPB outbreaks. Because we found MPB infestations in stands of <150 ft^2, we also used stands with basal areas between 120 and 150 if the average diameter was > 8 inches and at least 10 acres of the susceptible stand existed. When a suitable stand was found, a set of four 2.5-acre plots was installed. The plots were inventoried by subdividing the central 1.25 acres of each 2.5-acre plot into five equal strips and measuring the diameter at breast height (d.b.h.) of each live tree in the strip. Diameter measurements were used to calculate GSL, basal area per acre, and average diameter. Leave trees were selected on the basis of diameter, spacing, apparent health, and crown development. Each set of plots usually has three plots partially cut to either GSLs of 60, 80, and 100 or 80, 100, and 120 plus one uncut plot serving as a control.

Although nine sets of plots have been installed on the Black Hills National Forest, only the White House Gulch plots—a set of four plots about 10 miles northwest of Custer, SD—have been exposed to or are currently being subjected to an MPB epidemic. The plots consist of three plots partially cut to GSLs 60, 80, and 100 plus an uncut control of GSL 128. Other plot characteristics are listed in table 1.

The plots were installed in May 1989 at which time all inventory and tree selection work was completed. However, the plots were not cut until January 1990. Because the MPB emerges and attacks trees in late July-early August (Schmid 1972), the plots to be partially cut were in the uncut state during the MPB emergence and attack period in 1989. The plots were reinventoried in September 1990 and late August 1991 at which time each tree was classified as infested or noninfested. The number of infested trees was summarized by 1-inch diameter class by year within each GSL. No statistical tests were performed.

To determine the radial growth for trees in the GSL 100 and the control during 1989–1991, increment cores were removed on Sept. 23, 1991. Cores were removed from fourteen 12-inch trees (diameter range 11.6–12.5) in the GSL 100. At the same time, increment cores were taken from 16 trees in the control plot: ten 12-inch green trees and six 1991 MPB-infested trees of various diameters. Annual radial increment was measured to the nearest 0.001 inch for each of the last 10 years. Annual increment for years 1 and 2, 1991 and 1990 respectively, were separately compared to year 3 (year 1989) in paired t-tests, $\alpha = 0.05$.

Results and Discussion

Tree mortality was observed in all plots in 1989 (table 2). Mortality was not significantly different among the plots in 1989 although the beetle-killed trees in the GSLs 60 and 80 were near the periphery of each plot. None of the partially cut plots had infested trees in 1990 and 1991, but the uncut control had 19 and 17 infested trees respectively for those two years. Mortality in the GSL 60, 80, and 100 plots was expected in 1989 because the plots were uncut during the 1989 MPB attack period. The absence of tree mortality in the GSL 60, 80 and 100 plots after the plots were cut (i.e., January 1990) suggests that stands cut to GSL ≤100 are less susceptible to MPB attack even though their average diameters were in the susceptible-size category of ≥8 inches (table 1).

The critical threshold for MPB infestation in ponderosa pine stands may be the GSL 120 level. While the White House Gulch stands of GSL ≤100 were not infested since cutting, these stands and the control were sustaining mortality prior to cutting when their GSLs were between 120 and 130 (see table 1). A GSL 120 stand in another set of plots also suffered some tree mortality (J. M. Schmid, unpublished data). Unfortunately, the infestation in that stand lasted only one year and subsequent infestation of the GSL 120 plot or any of the other plots including the control did not occur. Thus, the threshold for MPB infestation of susceptible-sized trees appears to be about GSL 120, considerably less than the GSL ≥150 of Sartwell and Stevens (1975).

The difference in our critical threshold of GSL 120 and the 150 ft^2 of basal area per acre of Sartwell and Stevens (1975) relates to scale of measurement and stand densities existing at the time of the MPB epidemics. Sartwell and Stevens (1975) used the apparent center of an infested group as the focal point for a plot of unspecified radius and size to determine the stand density level of the infested group. Our stand density level of GSL 120 represents the level for 2.5 acres. In addition, stand densities were higher in the northern Black Hills in the 1970's when Sartwell and Stevens sampled MPB-infested groups. We realize that the MPB may infest spots within a stand where the density exceeds the general level of most of the stand because of stand heterogeneity. However, the GSLs on any of the strips within any of the White House Gulch plots rarely exceeded GSL 135 prior to cutting. Thus, GSL 120 is more appropriately the threshold for MPB infestation.

Table 1.—Stand characteristics of the White House Gulch ponderosa pine plots.

Growing stock level	Original GSL	After partial cutting					
		GSL	Mean dia	BA/A	Trs/A	Mean age	Site index
60	123	58.6	12.5	59	68	86	70
80	126	79.2	11.2	79	115	85	65
100	122	100.2	11.6	100	134	89	66
Control	128	128.5	10.8	128	199	88	67

Table 2.—Numbers of mountain pine beetle-killed trees in the White House Gulch growing stock level plots by diameter class and year of infestation.

Tree d.b.h. (inches)	GSL 60			GSL 80			GSL 100			Control		
Year...	89	90	91	89	90	91	89	90	91	89	90	91
7	0	0	0	0	0	0	0	0	0	0	2	0
8	0	0	0	0	0	0	0	0	0	2	0	0
9	0	0	0	0	0	0	1	0	0	1	0	5
10	0	0	0	1	0	0	1	0	0	3	6	1
11	0	0	0	2	0	0	3	0	0	2	4	6
12	1	0	0	2	0	0	3	0	0	1	4	3
13	0	0	0	1	0	0	0	0	0	2	2	2
14	0	0	0	0	0	0	0	0	0	0	1	0
15	1	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	1	0	0
Total	2	0	0	6	0	0	8	0	0	12	19	17
Percent (%) of original stand	<1			1			2			2.5	3.9	3.5

The establishment of the GSL 120 as the threshold for MPB infestation has critical implications for cutting practices in the Black Hills. Prior to this study, managed stands of GSLs 100 to 140 were thought to be less susceptible because they were below the GSL 150 threshold (Alexander 1987). Now, stands of GSLs 120 to 140 should be considered just as susceptible as stands with GSL ≥150. Forest managers can still elect to carry stands at these densities, but they must maintain constant vigilance over such stands and take appropriate action when MPB infestations appear. Further, although susceptible trees cannot be differentiated on the basis of diameter alone when the diameters are ≥8 inches (Alexander 1987), the presence of unattacked susceptible-sized trees in the GSLs 60 to 100 suggests that the susceptibility of such trees can be decreased by reducing stand density and increasing tree spacing.

Our results were inconclusive regarding the relative importance of tree resistance (Berryman 1976) versus microclimate (Bartos and Amman 1989) in preventing subsequent infestation in the partially cut plots. Prior to determining growth rates in the GSL 100 and the control, we thought microclimate was probably more responsible for the lack of reinfestation after cutting because Schmid et al. (1991) found the diameter growth in the residual trees in partially cut stands and their respective uncut control in another set of GSL plots did not differ for the first two years following cutting. However, the trees in those plots were responding under drought conditions, so an increased growth rate in the cut stands would not be expected immediately. When we sampled trees in the GSL 100 and control plot in September 1991, diameter growth had increased significantly in 1990 and 1991 (the two years following cutting) as compared to 1989. Precipitation on the plots during May 15-August 15, 1990 totaled more than 10 inches (J. M. Schmid, unpublished data) and the residual trees in the GSL 100 may have used this precipitation to increase their resistance. However, diameter growth in the trees in the control plot also increased significantly in 1990 and 1991 in comparison to 1989, but their resistance was not apparently increased because tree mortality continued. Further, even though the mean diameter growth in the GSL 100 was statistically significant between 1990 and 1989, the difference was only 0.02 to 0.03 inches. A difference of this magnitude would hardly seem influential in discouraging MPB attack. Thus, while neither hypothesis is conclusively supported, the data seem to support the microclimate hypothesis. The data do not conclusively support microclimate because diameter growth may not have been the best expression of resistance. A better expression of resistance may have been the water balance in the trees although diameter growth remains the most practical expression of resistance.

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